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Bird Homogenization at regional scale (Umbria, central Italy): a lack of evidence for a change in the 2001-2014 period

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Abstract – The decline of stenoecious species and the development of euryoecious species are causing a flattening of communities, which gradually lose their peculiar characteristics ending up being more and more similar among themselves and causing a general loss of biodiversity. Amongst the various causes of this phenomenon, known as 'functional homogenization' (FH), lies the urbanization which is responsible for the alteration of semi natural and natural environment. The environmental transformation is also affecting Umbria (a region in the centre of Italy) where in recent years there has been a significant intensification of this phenomenon. The purpose of the study is to verify whether FH is also happening in this region by analyzing the community of breeding birds to a regional level. Starting from a sample of 1,696 bird watching stations covered between 2001 and 2014, using the software TRIM it was possible to analyze the trend of 132 bird species classified as specialists and generalists in terms of habitat-selection. Furthermore, for each year taken into account it has been calculated the value of *Community Specialization Index* (CSI – Filippi-Codaccioni *et al.*, 2010), an indicator of the importance of specialist species within the whole regional bird community. Finally, it was considered the degree of difference amongst the bird communities from different parts of the region (subdivided into 102 UTM squares each covering an area of 100 km^2) using the average Euclidean distance (AED) between the various squares which was calculated based on the levels of abundance of the different species. The presence of FH would have implied the following: a tendency of increase of generalist species, a decrease of the specialists, a CSI reduction, a AED reduction. During the period considered it was observed that there was an increase of over half (50.7%) of generalist species, whereas just 23.2% was declining. Amongst the specialists, the declining species were equal to those increased (12.7%). Although there was an increment of the generalist species, the indexes CSI and AED did not show any significant trend (Spearman test). Overall, our findings do not describe the occurrence of a homogenization process in the last decade of the regional bird community as a whole.

Key-words: homogenization, bird communities, Central Italy.

INTRODUCTION

The term 'biotic homogenization' (*biotic homogenization*, BH - Olden 2006a, Olden 2006b) refers to the process through which two or more communities increase their similarity through time. There are two main aspects that can be identified in this process (Clavel *et al.* 2001):

- The *functional homogenization* (FH) consisting in a reduction of the variety of functions (the degree of specialization) of species belonging to a community;
- The *taxonomic homogenization* (TH) consisting in a communities' tendency to merge between them in terms of specific composition.

Typically, FH happens when euryoecious species (generalists) replace stenoecious species (specialists): when the phenomenon takes place simultaneously in different environments from the same geographic area, there is an invasion of the corresponding communities by generalist species, ultimately resulting in a TH condition. Conversely, the TH condition alone does not necessarily imply the FH; for instance, TH may appear also following the introduction of species (generalists and not) outside their natural range (Blair 2001).

In literature, there are growing evidences that the decline of specialist species is a phenomenon widely common, extended to different geographical contexts and to many systematic groups (Fisher & Stocklin 1997, Warren *et al.* 2001, Fisher *et al.* 2003, Kotze & O'Hara 2003, Julliard *et al.* 2004, Rooney *et al.* 2004). The mass extinction events which took place in geological times seem to have involved mainly highly specialized organisms, sparing a higher proportion of generalist forms (McKinney 1997). It is believed that most of the specialist's vulnerability is due to the poor ability to adapt to changing environmental conditions (Clavel *et al*. 2011): although when in their specific habitat these species are able to use the resources to their best showing a *fitness* by far superior than the generalists, when placed in other environments they prove to be way less efficient. On the contrary, the generalists are not able to reach the same efficiency level which is typical of specialist species when placed in their typical habitats, however they are able to adapt to a wide range of environments. It follows that the generalists are more prone to be able to cope with any environment changing perturbation while such changes may result to be fatal to the specialists. It is clear that the substitution of specialist species in disturbed environments by generalist species, implies a high degree of erosion of species variability on a regional level; for this reason, the proportion of specialist species within a community can be read as a good indicator of biodiversity level (Clavel *et al*. 2011). This theory is much stronger when considering that the indicators mostly used (species richness and diversity measured on a local scale) can be misleading: in different study cases (Lennon *et al*. 2004, Sizling *et al*. 2009, Filippi-Codaccioni *et al*. 2010) it was highlighted a negative connection of these parameters with the average level of specialization or rarity of the species which are part of the considered communities; in other words the richest and most varied communities were mainly composed of common and generalist species, whereas in poorer and monotone communities it was noted the presence of rare and specialized species.

Urbanization is one of the main reasons why BH phenomenon occurs (McKinney 2006, Smart *et al*. 2006, Devictor *et al.* 2007, Sorace & Gustin 2008). This type of environmental transformation has undoubtedly affected Umbria (Central Italy) whose territory has had different estimates of land uptake which were not always congruent:

- Ecological regional network (AA.VV. 2009): 5.1% of regional surface in 1999, with a higher concentration in flat areas;
- Romano & Zullo (2010): 1.9% in 1956; 3.6% in 2002;
- Munafò & Tombolini (2014): 1.8% (± 0.7) in the 50's; 4.3% (± 0.8) in 1998; 5.6% (± 2.3) in 2012.

If we consider the last source (the most complete in terms of observation through time), it is evident how urbanization did not have a linear progression, on the contrary, it showed a considerable acceleration in terms of annual increase. In view of this statement, it was decided as a matter of urgency to verify whether the typical process of biotic homogenization took place also in Umbria. This was obtained by examining the recent evolution of the regional community of breeding birds during a ten-year period: this was the purpose of the actual study. In contrast with other European studies, which are mainly focused on the outcome of the phenomenon within the same urbanized areas (Clergeau *et al*. 2006, Devictor *et al*. 2007, Devictor *et al*. 2008, Sorace & Gustin 2008), the perspective considered here is quite different; the aim is to understand whether the increase of the urbanization level observed during the study period may have had as a consequence the deterioration of the state of conservation of the regional avifauna as a whole, not strictly based on a local scale. As far as we know, this is perhaps the very first study of this kind in our continent.

More specifically, the theories that we aim to verify are the following:

a) the increase of similarity between the communities of different regional sub-areas;
b) the reduction of the population within the specialist species;
c) the increase of the population within the generalist species;
d) the reduction of the importance of specialist species within the whole regional community.

The first theory is connected to a generic TH condition, while the remaining three others are specifically linked to the FH process. The potential proof of existence of all four theories would provide a strong evidence of how in Umbria, during the ten years considered, there was a biotic homogenization phenomenon on a regional scale, also clarifying its way of development (substitution of specialist species by generalist species). Finally, it is important to point out how the present research is the first attempt for Umbria to apply biodiversity indicators (focused on avifauna) which are based on the specialization concept, rather than being based on other community's parameters such as species richness and diversity (Velatta *et al*. 2010, Velatta & Montefameglio 2011) or based on the combination of time trends belonging to species that are sharing the same habitat (Velatta *et al*. 2009, 2013).

MATERIALS AND METHODS

Ornithological data collection in the field

The data considered here was collected during the regional monitoring program of breeding birds and was previously used for other types of analysis (Velatta *et al*. 2009, 2010, 2013, Velatta 2010, 2013).

Between 2000 and 2014 (excluding 2006) a team of ornithologists in two months (May-June) covered 1,696 stations which were distributed within the entire Umbrian territory and corresponding as a whole to a representative sample of regional environments (Velatta *et al*. 2010). The number of visited stations varied between a minimum of 1,263 in 2011 and a maximum of 1,677 in 2008 (Tab. 1); the stations regularly checked every year were 1,128. The method used was the same as the one adopted in the national project MITO2000 (Fornasari *et al.* 2002): point-counts of 10 minutes each, which took place in the first few hours past dawn and making a distinction between the contacts occurred within and beyond 100-meter distance from the surveyor. Nocturnal species (Strigiformes and Nightjar, *Caprimulgus europaeus*) were excluded from the data process as the methodology utilized is not suitable to collect data from them. The species belonging to the *Sylvia cantillans* complex (*Sylvia cantillans* and *Sylvia subalpina*) were considered as a one only species since their taxonomic separation only took place past the beginning of the data collection (Brambilla *et al.* 2008).

Evaluation of heterogeneity degree of regional communities

First of all were taken in consideration the 102 UTM squares (time zone 33) with a 10 km side in which the regional territory is divided. For every single square was calculated the annual value of IPA (Indice Ponctuel d'Abondance - Point counts of Abundance Index) of every species, which is given by the ratio between the number of individuals detected and the number of stations covered (Blondel *et al.* 1970, modified). In order to have comparable data over time only the stations that were covered every year have been considered. For every year was calculated the Euclidean distance between all possible square couples, using as variables (dimensions) the IPA values of all n species observed in at least one of the two squares:

$$ED_{(A\text{-}B)} = \sqrt{[(IPA_{A1} - IPA_{B1})^2 + (IPA_{A2} - IPA_{B2})^2 + ... + (IPA_{An} - IPA_{Bn})^2]}$$

where: $ED_{(A\text{-}B)}$ is the Euclidean distance between the squares A and B; IPA_{Ax} and IPA_{Bx} are the values of IPA from the x^{th} species respectively in square A and square B. The average Euclidean distance between UTM squares (abbreviated in AED) can be considered as an indicator of the heterogeneity degree of bird communities from different regional parts. The existence of AED time trend was investigated through the Spearman test. All statistic elaborations (including those described later) were carried out, unless differently specified, through the software package SPSS 11.5 version.

In the event of biotic homogenization, a significant reduction of the AED index is expected in line with hypothesis a).

Table 1. Number of point-counts carried out by year.

Year	Number of station
2000	1647
2001	1666
2002	1672
2003	1674
2004	1646
2005	1666
2006	0
2007	1675
2008	1677
2009	1668
2010	1325
2011	1263
2012	1666
2013	1656
2014	1673

Species Specialization Index calculation

The *Species Specialization Index* (SSI – Devictor *et al.* 2008) is an indicator which refers to the specialization degree of a certain species in terms of habitat choice. There are two main reasons why the value calculation on the observed species was done:

- to allow the identification of specialists and generalists species;
- because the SSI value is necessary to determine the annual values of the *Community Specialization Index* (CSI - Filippi-Codaccioni *et al*. 2010), an estimator of the importance of specialist species within the regional community.

In order to find out the SSI values of each species, the land use in the surrounding of every survey station was determined (within a range of 100 meters) through the use of the software ARCMAP version 9.1. In doing so, the geobotanical map of Umbria (Orsomando *et al.* 2004) was used as primary base. The individual stations were allocated in 12 environmental categories (described in ESM 1 - Electronic Supplementary Material), the same previously adopted when analyzing the regional bird communities (Velatta *et al.* 2010): wetland areas and their ecotones; woods of sclerophyllous evergreens; planitial, hillside and sub- mountainous deciduous woods; mountainous deciduous woods; conifer reforestation; hillside prairies; mountain prairies; arable lands without natural spaces; arable lands with some natural spaces; mixed plant cultivation, without natural spaces; mixed plant cultivation, with some natural spaces; urbanized areas.

The number of stations that was possible to attribute to one of the 12 categories mentioned above is 954; the remaining stations, characterized by a high environmental heterogeneity, were not considered when calculating the SSI values.

For every species was calculated the value of IPA in each of 12 environmental categories of reference, obtained as the ratio between the number of individuals detected in the selected environment (considering just the contacts within 100 meters) and the number of point-counts carried out in the same location. The SSI value of every single species was calculated as:

$$\frac{SD}{IPA_{mean}}$$

where: IPA_{mean} is the average of IPA values obtained for the species examined in the 12 different environments; SD its standard deviation.

Specialist species show high IPA differences amongst the various environments and as a consequence they have high SSI values; evidently the opposite happens to those species less demanding in terms of habitat (generalists). For the purpose of the present study, it was decided to define as specialists all those species whose SSI value is superior to the average value of the species found during the research; and generalists all those species where the SSI is below average.

For 69 species, habitat extent indexes (AH) were already obtained in the past (Velatta *et al.* 2010) through the Pielou's formula (1969). In order to verify the reliability of the SSI index, a correlation analysis was carried out (Spearman test) between SSI values and their corresponding AH values.

Individual species trends

For each species of 132 recorded, the software package TRIM version 3.53 (Pannekoek & van Strien 2005) was used to analyze its trend and compute its annual population index. This index is obtained by dividing the number of individuals present in a specific year sample with the number of individuals present in a year of reference, usually the first of the series.

With this purpose all contacts obtained in the 1696 stations were used with no distance limit from the watcher. The first year of survey (2000) was excluded from the analysis; this was necessary in order to avoid any possible distortion due to the increasing surveyors' efficiency which takes place between the first and the second year, causing an ostensible growth of population (Kendall *et al.* 1996). So, trends and population indices refer to the 2001-2014 period.

In order to acquire the trend, TRIM utilizes a log-linear regression procedure which provides an estimate of **b** factor, which conveys the population's average annual variation during the study period; the number of bird expected by the log-linear model in a set year is given by the number of the previous year multiplied by b. Therefore, if $b = 1$ the population is stable; if $b < 1$ the population is decreasing; if $b>1$ the population is increasing. TRIM also provides the standard error of b, from which it is possible to extract its confidence interval (with a probability level of 95%) on which base the trend classification is made.

TRIM is also able to overcome the problem of possible missed coverage of one or more sample sites which may take place over the years, providing an estimate of the missing values based on the observed values in that same year on the covered sites. The total of individuals detected in the stations effectively covered together with the individuals estimated to be present in the stations that were skipped, is defined in the TRIM output as *imputed time total.*

In our case TRIM was utilized following the below modality:

- every station was considered as an independent site;
- no covariates were introduced;
- type 2 model (linear trend) was used, if possible with stepwise procedure to select the points where the slope of the log-linear equation changes (changepoints);
- for the estimate of the equation parameters and of their standard error was utilized the GEE (Generalized Estimating Equations) procedure, which takes into account both the possible deviation of abundance data from a Poisson distribution, and their possible serial correlation.

The year 2006, when the survey did not take place, was ignored, because without all stations data it is not possible to estimate the missing values.

Multi-species trend indicators

Two multi-species trend indicators were obtained for both specialist and generalist species, similar in concept to *Farmland Bird Index*, FBI and *Woodland Bird Index,* WBI (Gregory *et al.* 2005). More specifically the two indicators were obtained by doing the geometric average of the annual population indices in specialist species (*Specialist Bird Index,* SBI) and in generalist species (*Generalist Bird Index,* GBI).

All the species for which TRIM was not able to provide a trend estimate or for which the diagnosis was of uncertain trend were excluded from the SBI and GBI calculation, as well as all the species whose index of population proved to be of zero value in one or more years (Lanner Falcon *Falco biarmicus* and Cattle Egret *Bubulcus ibis*) since the geometric average cannot be calculated on data matrix containing zero values.

In the SBI calculation, all species alien to the Umbrian fauna (Mute Swan *Cygnus olor* and Red-legged Partridge *Alectoris rufa*) were excluded too, because their introduced taxa status makes it possible for them to be considered potential homogenization elements (even though they are specialists).

The existence of SBI and GBI time trend was checked using the Spearman test. In the event of biotic homogenization, it is expected to observe a significant reduction of the first index and a significant increase of the second index, in line with theories b) and c).

Community Specialization Index Calculation

The *Community Specialization Index* (CSI-Filippi-Codaccioni *et al.* 2010) is an estimator of the importance of specialist species within a community. It is calculated annually as:

$$\sum_{i=1}^{n} (a_i * SSI_i) / \sum_{i=1}^{n} a_i$$

where, for every i^{th} species in n species making the community, a_i is the abundance value estimated by TRIM for the examined year (*imputed time total*) and SSI_i is the Species Specialization Index (see above), identical for all years. To summarize CSI is SSI average value of those individuals making up the examined community.

All species alien to the local fauna were excluded from CSI calculation (due to the same reasons mentioned before).

The existence of CSI time trend was also examined through the Spearman test. In the event of biotic homogenization, it is expected to have a significant index reduction, as anticipated by theory d).

Table 2. Trends of the indices related to the biotic homogenization process (Spearman test; significant values are shown in bold type).

Index	Spearman's rho	$P_{2\text{-tailed}}$	N
GBI	**0.637**	**0.019**	13
SBI	-0.088	0.775	13
CSI	0.231	0.448	13
AED	0.060	0.845	13

RESULTS

The AED index did not show any significant trend (Fig. 1, Tab. 2) regardless of a notable increase in the last year. The SSI index proved to be inversely correlated to AH in a highly significant way (r_s = - 0.901; $P_{2\text{-tailed}}$ = 0.000; N = 69) thus showing its suitability in evaluating the degree of habitat specialization for a given species. Its values ranged from a minimum of 0.285 to a maximum of 3.464 (Tab. 3), with an average equal to 1.927. The generalist species (SSI < average) were 69, the specialist species (SSI > average) 63.

Out of 132 examined species, TRIM was able to proceed with a trend estimate in 129 cases (results are shown in ESM 2). Those species with uncertain trend were 10.1% between generalist species and 61.9% amongst the specialists (Tab. 4); the higher degree of uncertainty which characterizes the second category is most likely due to the greater number of rare species belonging to the latter.

The number of growing species was superior to the number of decreasing species (43 vs. 24), however the related proportions turned out to be very different between the species categories:

- generalists: 50.7% increasing against 23.2% decreasing;
- specialists: 12.7% increasing and the same decreasing.

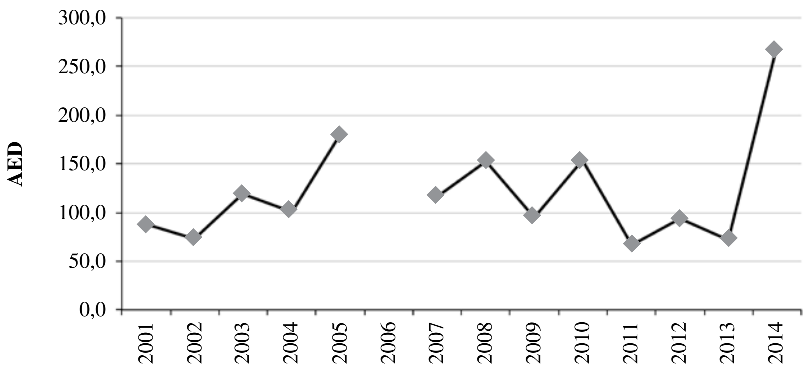

Figure 1. Trend of the Average Euclidean Distance (AED).

Table 3. Recorded species with their corresponding Species Specialisation Index values. Species are listed in decreasing order of SSI.

Species	SSI	Category
Cygnus olor	3.464	specialist
Anas strepera	3.464	specialist
Anas crecca	3.464	specialist
Aythya nyroca	3.464	specialist
Alectoris graeca	3.464	specialist
Ixobrychus minutus	3.464	specialist
Ardeola ralloides	3.464	specialist
Casmerodius albus	3.464	specialist
Ardea purpurea	3.464	specialist
Falco biarmicus	3.464	specialist
Rallus aquaticus	3.464	specialist
Porzana parva	3.464	specialist
Himantopus himantopus	3.464	specialist
Charadrius dubius	3.464	specialist
Actitis hypoleucos	3.464	specialist
Ptyonoprogne rupestris	3.464	specialist
Cinclus cinclus	3.464	specialist
Certhia familiaris	3.464	specialist
Fulica atra	3.456	specialist
Chroicocephalus ridibundus	3.453	specialist
Podiceps cristatus	3.452	specialist
Acrocephalus arundinaceus	3.433	specialist
Anas platyrhynchos	3.411	specialist
Acrocephalus scirpaceus	3.399	specialist
Oenanthe oenanthe	3.323	specialist
Pyrrhocorax pyrrhocorax	3.323	specialist
Anthus campestris	3.251	specialist
Larus michahellis	3.189	specialist
Ardea cinerea	3.184	specialist
Phylloscopus sibilatrix	3.181	specialist
Egretta garzetta	3.175	specialist
Alcedo atthis	3.158	specialist
Gallinula chloropus	3.140	specialist
Remiz pendulinus	3.139	specialist
Tachybaptus ruficollis	3.023	specialist
Calandrella brachydactyla	2.951	specialist
Nycticorax nycticorax	2.887	specialist
Emberiza citrinella	2.867	specialist
Sylvia undata	2.735	specialist
Saxicola rubetra	2.635	specialist
Phalacrocorax carbo	2.630	specialist
Cettia cetti	2.501	specialist
Alectoris rufa	2.497	specialist
Monticola saxatilis	2.476	specialist
Circus aeruginosus	2.447	specialist

Species	SSI	Category
Sylvia hortensis	2.420	specialist
Riparia riparia	2.382	specialist
Coccothraustes coccothraustes	2.364	specialist
Falco peregrinus	2.359	specialist
Circus pygargus	2.323	specialist
Anthus trivialis	2.318	specialist
Alauda arvensis	2.314	specialist
Aquila chrysaetos	2.299	specialist
Periparus ater	2.270	specialist
Monticola solitarius	2.266	specialist
Carduelis cannabina	2.243	specialist
Accipiter gentilis	2.213	specialist
Pyrrhula pyrrhula	2.210	specialist
Bubulcus ibis	2.136	specialist
Turdus philomelos	2.120	specialist
Merops apiaster	2.004	specialist
Dendrocopos minor	1.972	specialist
Lanius senator	1.932	specialist
Perdix perdix	1.903	generalist
Acrocephalus palustris	1.896	generalist
Motacilla flava	1.835	generalist
Petronia petronia	1.813	generalist
Poecile palustris	1.687	generalist
Galerida cristata	1.571	generalist
Turdus viscivorus	1.562	generalist
Phylloscopus bonelli	1.540	generalist
Emberiza hortulana	1.483	generalist
Regulus ignicapilla	1.468	generalist
Milvus migrans	1.363	generalist
Coturnix coturnix	1.343	generalist
Phoenicurus ochruros	1.339	generalist
Sitta europaea	1.314	generalist
Sturnus vulgaris	1.273	generalist
Circaetus gallicus	1.272	generalist
Accipiter nisus	1.256	generalist
Motacilla cinerea	1.241	generalist
Sylvia cantillans and S. subalpina	1.225	generalist
Lanius collurio	1.213	generalist
Sylvia melanocephala	1.201	generalist
Passer montanus	1.189	generalist
Emberiza cia	1.189	generalist
Dendrocopos major	1.183	generalist
Sylvia communis	1.179	generalist
Cisticola juncidis	1.173	generalist
Phylloscopus collybita	1.168	generalist

continued

Species	SSI	Category
Emberiza calandra	1.152	generalist
Streptopelia decaocto	1.128	generalist
Passer italiae	1.059	generalist
Cuculus canorus	1.056	generalist
Delichon urbicum	1.047	generalist
Erithacus rubecula	0.991	generalist
Corvus monedula	0.986	generalist
Phasianus colchicus	0.976	generalist
Phoenicurus phoenicurus	0.944	generalist
Pernis apivorus	0.934	generalist
Lullula arborea	0.916	generalist
Hippolais polyglotta	0.916	generalist
Hirundo rustica	0.888	generalist
Pica pica	0.857	generalist
Muscicapa striata	0.836	generalist
Falco subbuteo	0.831	generalist
Falco tinnunculus	0.825	generalist
Certhia brachydactyla	0.817	generalist
Luscinia megarhynchos	0.815	generalist
Saxicola torquatus	0.798	generalist
Jynx torquilla	0.791	generalist

Species	SSI	Category
Serinus serinus	0.784	generalist
Emberiza cirlus	0.772	generalist
Troglodytes troglodytes	0.713	generalist
Garrulus glandarius	0.688	generalist
Carduelis carduelis	0.679	generalist
Buteo buteo	0.650	generalist
Picus viridis	0.629	generalist
Columba palumbus	0.616	generalist
Motacilla alba	0.612	generalist
Upupa epops	0.587	generalist
Aegithalos caudatus	0.585	generalist
Fringilla coelebs	0.585	generalist
Streptopelia turtur	0.581	generalist
Apus apus	0.547	generalist
Oriolus oriolus	0.527	generalist
Corvus cornix	0.512	generalist
Carduelis chloris	0.507	generalist
Cyanistes caeruleus	0.497	generalist
Parus major	0.441	generalist
Turdus merula	0.325	generalist
Sylvia atricapilla	0.285	generalist

Table 4. Number of species by trend type.

Trend type	Generalist species		Specialist species		All species	
	N	%	N	%	N	%
Non ratable	0	0.0	3	4.8	3	2.3
Uncertain	7	10.1	39	61.9	46	34.8
Stable	11	15.9	5	7.9	16	12.1
Increase	35	50.7	8	12.7	43	32.6
Decrease	16	23.2	8	12.7	24	18.2
Total	**69**	**100.0**	**63**	**100.0**	**132**	**100.0**

Those species holding the adequate requirements to be inserted in the GBI and SBI calculation were respectively 62 (89.9% of generalists) and 19 (30.2% of specialists). Concerning GBI, it was observed a significant increment over the years (Fig. 2, Tab. 2), in accordance with the predominance amongst generalist species of those increasing; on the contrary no significant trend emerged within SBI. No significant trend was observed for CSI (Fig. 3, Tab. 2) despite showing a sudden increase in the last year just like AED.

DISCUSSION

The results obtained up till now are not sufficient to highlight (comparatively to the decade examined) the existence of a biotic homogenization process of the bird community on a regional scale.

The only result agreeing with this phenomenon is the widespread increase of the generalist species populations (with a consequently significant GBI increase). Such growth does not seem to have had a negative impact on

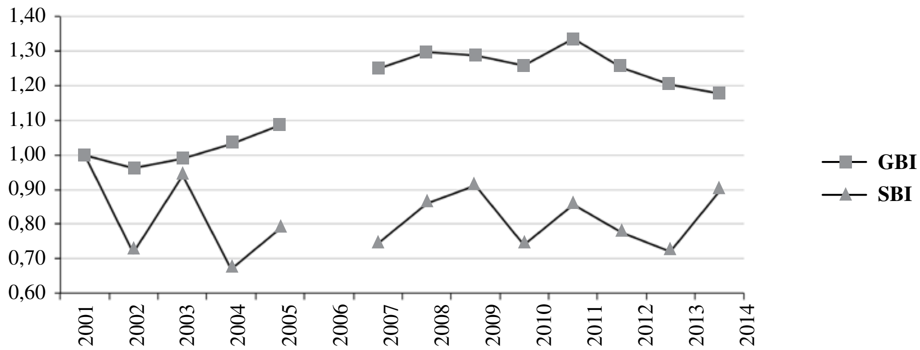

Figure 2. Trends of the multi-species trend indicators Generalist Bird Index (GBI) and Specialist Bird Index (SBI).

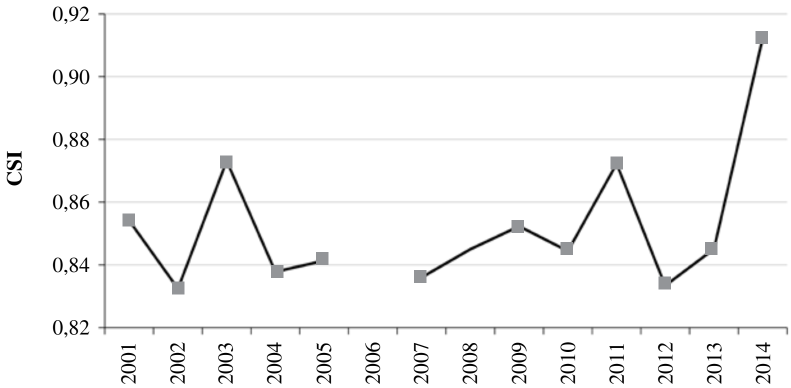

Figure 3. Trend of the Community Specialisation Index (CSI).

specialist species: amongst them, the percentage of decreasing species is not particularly high (12.7%) and the SBI does not show a significantly negative trend.

The absence of significant reductions within CSI and AED (which actually show higher values specifically in the last year) does not support the existence of a prevailing biotic homogenization phenomenon of bird communities in Umbria during the considered period.

The corresponding time of the two indices highest values suggests how the diversity between the communities of various sub-regional areas (expressed by AED) is more noticeable in the years where the specialist species are more abundant (expressed by CSI); the result is in line with the theory that the differences between the various communities are mainly determined by specialist species.

The lack of evidence of biotic homogenization on a regional scale, given the unquestionable increase of the urbanized surface, may have different possible explanations, which are contrasting at times:

- the percentage of urbanized surface is still relatively contained, when compared to other areas in Italy (Munafò & Tombolini 2014). Hence the urbanization homogenizing effects would be confined to limited areas and have little effect on the regional bird community as a whole. It is important to note that this does not mean that the urbanization did not have any effect on communities, those effects were merely confined to a local field;
- during a study in Argentina, Garaffa *et al.* (2009) underlined how low urbanization levels did not significantly alter, not even on a local level, the community's characteristics. It is therefore possible to suppose that in Umbria, during the analyzed period, the new urbanization may have spread on wide surfaces, without going beyond the critical threshold of buildings density that triggers the alteration processes of the local bird community;
- on the contrary Filippi-Codaccioni *et al.* (2008) observed how the effects of urbanization in France on the local bird communities, were more evident in the initial environmental transformation phase (between 0 and 25% of surface with buildings), while further al-

terations of the community due to the increase of the coverage of built up areas, proved to be of inferior range. In light of this, it is possible to suppose that in Umbria the new constructions might have been built in already urbanized areas and therefore already populated by modified communities, and that would also explain how there is a lack of evidence in the alteration of avifauna;

- the effects of a habitat loss due to urbanization may not be immediate, as they are compensated in a short period by the growth of the density of interested species within the remains of suitable habitats. This causes a situation of supersaturation known as *crowding* (Debinski & Holt 2000), which entails the reduction of the involved populations only after a lapse of time (Battisti 2003).

Based on the present knowledge, it is not possible to validate any of the four theories here above; in order to be able to verify them, it would be necessary to carry out an accurate investigation which could also take into account how the urban expansion took place (urban sprawl or the completion of already built up areas). Nonetheless the theme has a high applicative interest, as the explanation of these aspects would contribute to provide useful indications to urban planning, reducing the impact on avifauna of any future settlements.

Another important aspect to note is that the analyzed period (2001-2014) only includes the last phase of the urbanization process. The corresponding increase of the land uptake is computable at around 1.3% of the regional surface, which, based on Munafò & Tombolini (2014) evaluation, is given by the difference of values of 2012 and 1998. Between 1950 and 2012 the land uptake in Umbria was almost three times over (3.8% of the regional surface); however, given the lack of any standardized birds monitoring scheme prior to 2000, there is no way of assessing the effects of such a landscape transformation on bird populations. In other words: the documentation we have for bird populations relates to the last 14 years, which coincide with a relatively modest urbanization increase; therefore, it is not thinkable to exclude the possibility that during the previous period there may have been more evident transformations within bird communities caused by urbanization.

Finally, it is necessary to underline how the study has undoubtedly its limits, which will be overcome only through a further in-depth analysis:

- lack of definite trend for the majority of specialist species, resulting in a higher uncertainty degree of the effective SBI trend. In order to solve the inconvenience, it would be necessary to implement supplementary monitoring programs focusing on these species, to be carried out in the appropriate habitats (in particular wetlands and mountain areas);
- identification of specialist and generalist species purely based on one parameter (habitat). As much as relevant this aspect may be, it is not sufficient enough to determine the whole extent of a species ecological niche. It would therefore be desirable to improve the analysis by introducing evaluations related to other aspects of autoecology (for instance: trophic niche).

In future the progression of the monitoring activity, considering a wider time frame, together with the override of the limitations listed above, will allow to analyze more precisely the entity of the ongoing dynamics as well as the effective impact that urbanization has on the regional avifaunal biodiversity.

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